



NASA Glenn Propulsion Systems Lab (PSL) Icing Facility Update

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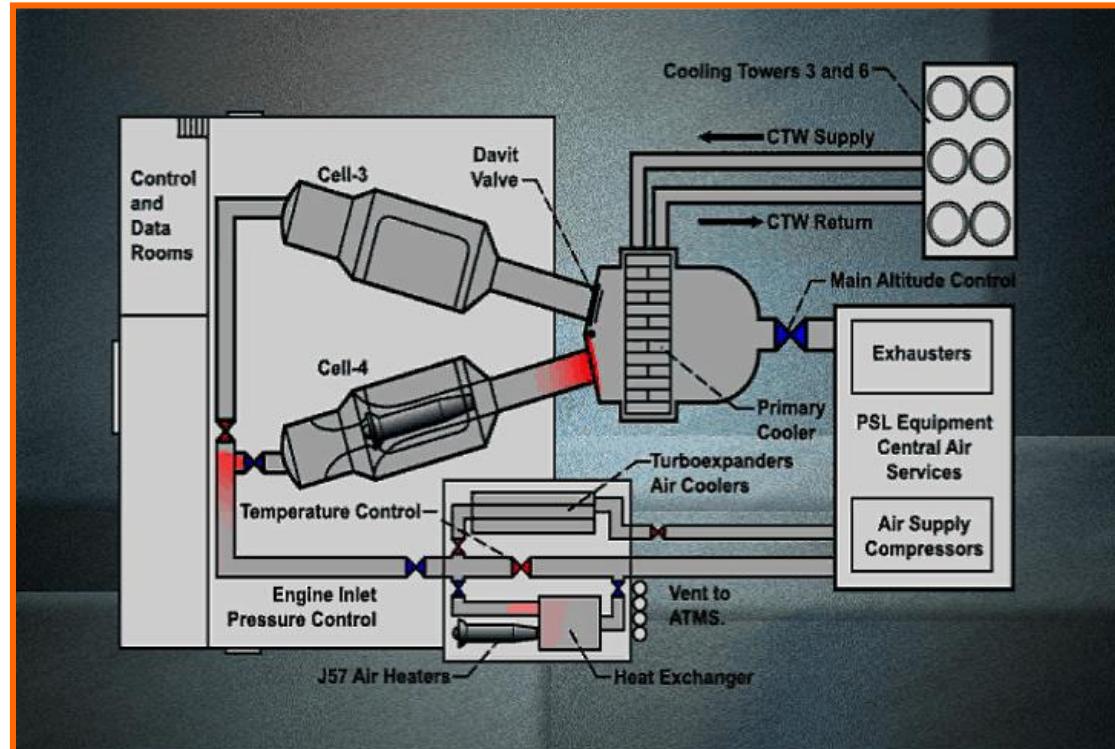
Outline

- PSL Background
- PSL Icing Status
- Icing System Design
- Facility Modifications
- Calibration
- Icing Testing Capabilities

PSL Background

NASA PSL is one of the Nation's Premier Direct Connect Altitude Simulation Facilities for Full-Scale Gas Turbine Engine and Propulsion System Research

- Two test sections share common inlet and exhaust
- Continuous Operation at high air flow rates
 - Altitude 90,000 ft (-90 deg F)
 - PSL-3 Mach 3.0 (600 deg F)
 - PSL-4 Mach 4.0 (1000 deg F)
- PSL3 recently upgraded for icing capability
- Multi-axis thrust measurement
- Real time, high speed data acquisition and display



NASA PSL Icing Status

- Initial icing calibration completed Nov. 2012
- Inaugural icing test of Honeywell ALF502-R5 engine completed April 2013.
- Second icing calibration completed June 2014.
- Second icing test was rig driven and completed March 2015
- Third icing calibration completed May 2015

Icing System Design

Specification	Min	Max
Engine / Rig Dia. (in cm)	24 60	72 180
Air Flow Rate (lbm/s kg/s)	10 5	330 150
Altitude, pressure (kft km)	4 1.2	50 15
Total Temp (°F °C)	-60 -50	50 10
Mach Number	0.15	0.80
TWC (g/m ³)	0.5	8.0 *
MVD (um)	15	>100 #

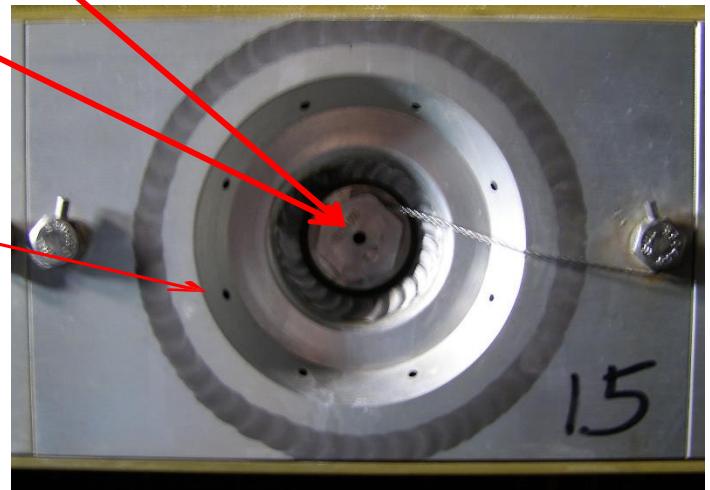
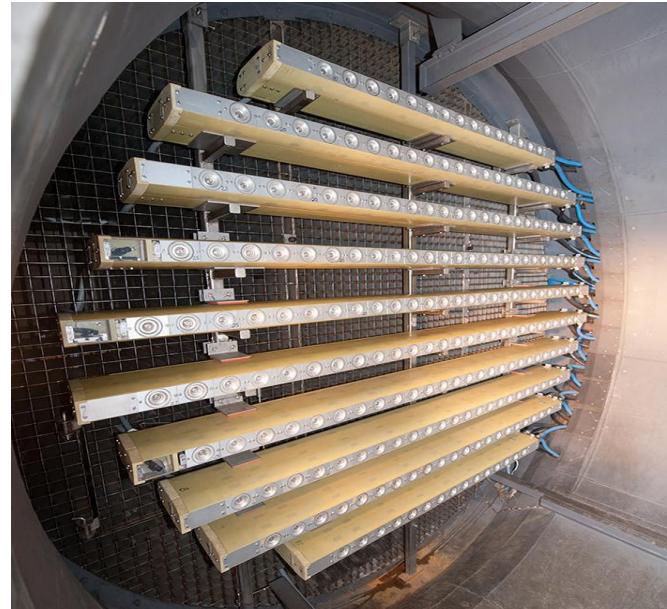
* Evidence that probe under-measured

Particles larger than ≈ 60 um are NOT fully glaciated.

PSL Icing Cloud Hardware

Spray Bars – Cloud Generation

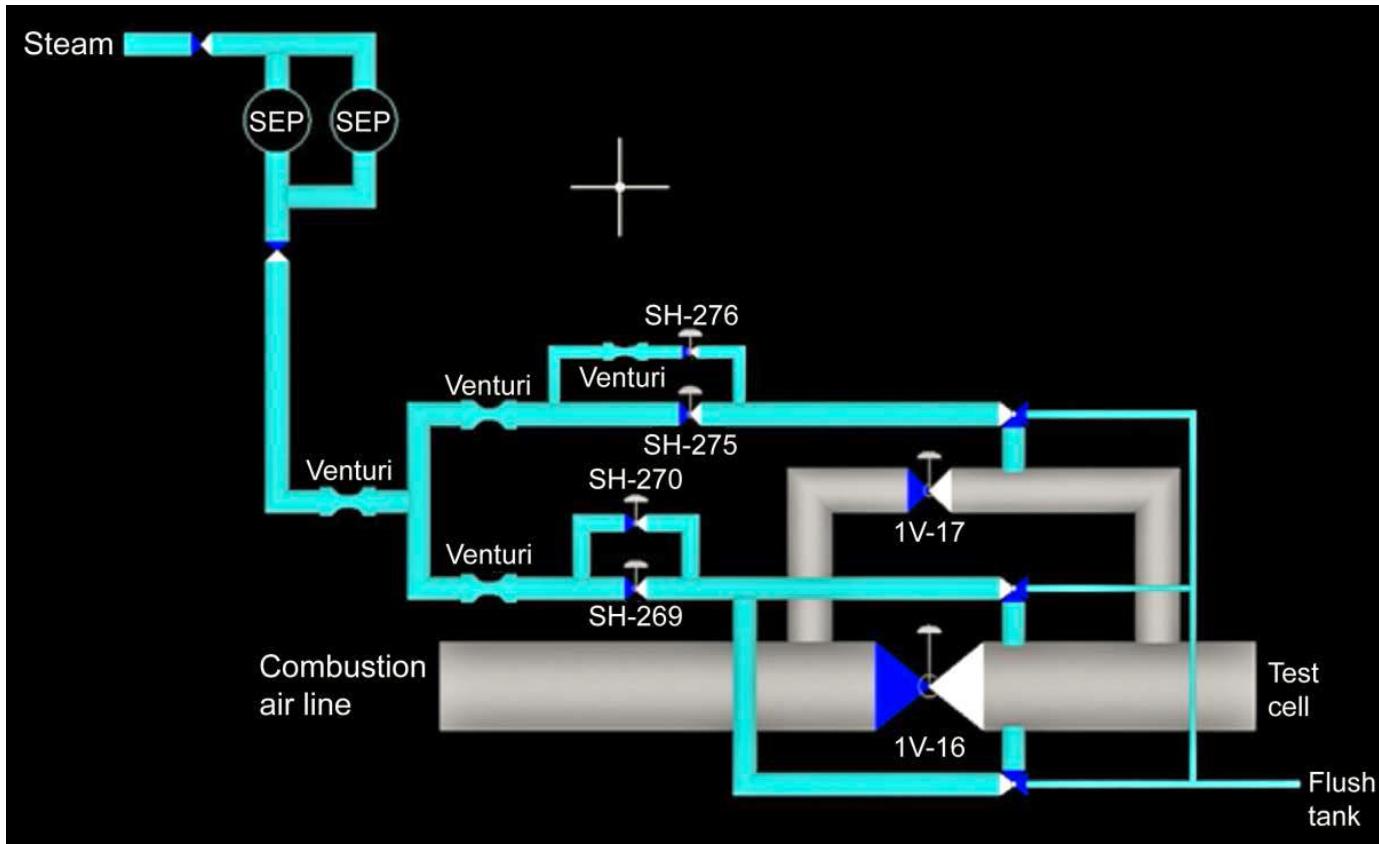
- Ten Spray Bars; total of 110 **Standard**
 - nozzles and 112 **Mod1** nozzles.
- Each nozzle is individually controlled.
- Nozzle controls:
 - **Pair**, atomizing air pressure: 10 – 90 psid, Tair temperature: 45 – 180 F.
 - **Pwat**, water pressure: 10 – 300 psid, Twat temperature: 45 – 180 F.
 - **DeltaP** = DP = (Pwat – Pair)
 - SBCA, Spraybar cooling air. P: 5 – 40 psid, T : -40 – 40 F.



$$(\text{Pair}, \Delta P) \Rightarrow (\text{MVD}, \text{TWC})$$

At a given air mass flow rate

Facility Modifications



Steam Injection System is used to provide a constant relative humidity in the inlet plenum to stabilize cloud.

Steam is injected into the inlet airstream as the supply air enters the building.

Relative humidity is measured at the injection point and in the inlet plenum.

Facility Modifications



Installed Deionized water system for Conventional Icing (CI). Can perform a continuous spray for up to 60 minutes.

- 600 – gallon tank takes 60 – 90 minutes to fill
- Monitor resistivity in real-time

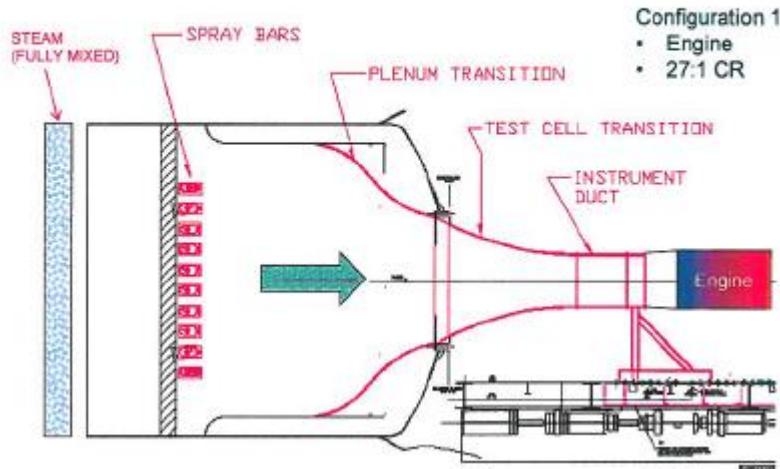
Facility Modifications



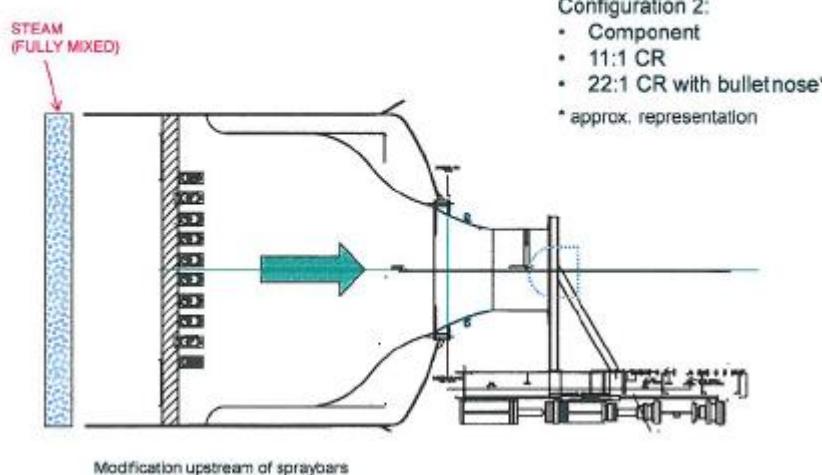
Tomography laser system installed and used on previous calibrations/tests to measure cloud uniformity.

Icing Calibration Configurations

PSL Configuration – 1st Cal



PSL Configuration – 2nd Cal



PSL Clouds

- Ice Crystals
 - Cold spray bar air & water temps
 - City or De-ionized water
 - Fully glaciated up to MVD 60 um
 - Wet Bulb temp < 0 C
- Supercooled Liquid
 - Hot spraybar air & water temps
- Supercooled Large Drops (SLD), but not bimodally distributed.

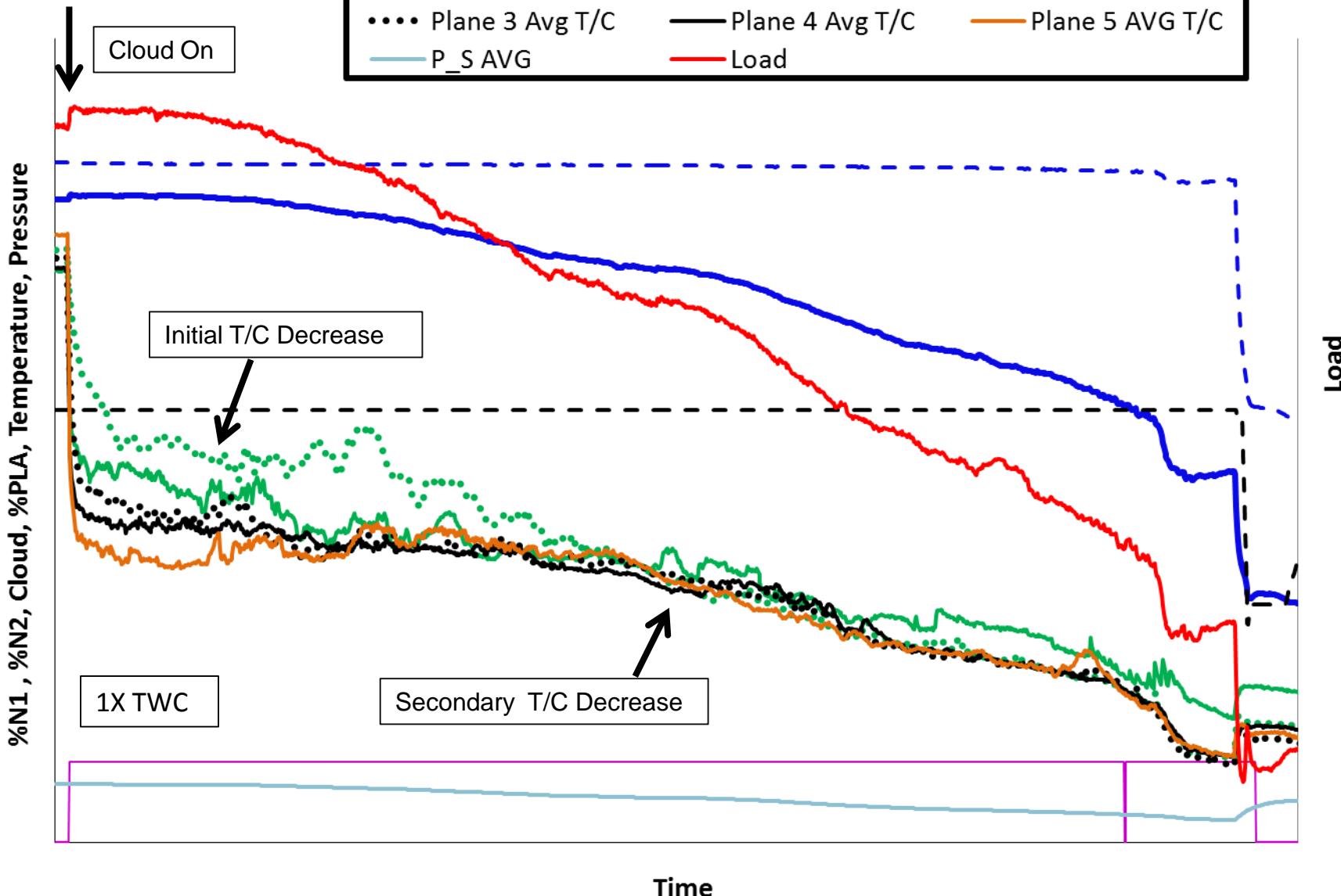
Inaugural Engine Icing Test

Honeywell ALF502R-5 engine installation in PSL. Validation test was able to replicate both roll back and non-roll back events previously experienced by the engine in flight test.



Rollback Indicators Chart- roll back test point

PSL-3, FLT850-2



Facility Icing Testing Capabilities

- Full sized Engines
 - Massflows up to 330 pps
 - Exhaust flows up to 500 pps
- Rig Tests
 - For engines that are too large to fit inside of PSL
 - Successfully completed a booster rig test in 2015

Summary

- Continuous flow facility
- Maintain a constant facility inlet temperature within +/- 2 deg F
- Maintain a constant relative humidity
- Vary cloud water content and particle sizes
- Run full scale engines
- Run LPC Driven Rigs



Questions?/Comments !

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